immerse
IMPROVING OCEAN MODELS
FOR THE COPERNICUS PROGRAMME

is-enes
INFRASTRUCTURE FOR THE EUROPEAN NETWORK
FOR EARTH SYSTEM MODELLING

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H2020 IMMERSE : Developing NEMO for improving Copernicus Marine Environment Services

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Outline

1. Project fact sheet
2. Project context and background
3. Project concept and objectives
4. Overview of planned activities
5. Interaction with key stakeholders
6. Concluding remarks

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Project fact sheets

- IMMERSE project selected in response to H2020 call LC-**SPACE**-03-EO-2018
- The project is led by CNRS and **started in Dec 2018 for 48 months** (until Dec 2022)
- IMMERSE gathers **a consortium of 14 institutions** across Europe :

Developing new capabilities for Copernicus Marine Services by improving NEMO ocean model

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Project context and background

- Ocean circulation models are **key tools** :
  - for building an **understanding** of the mechanisms governing ocean variability
  - for **climate projections** as components of Earth System Models
  - for **operational forecasts** as components of operational prediction systems
  - for **preparing ocean observing systems** (OSSE/OSE for in-situ and satellite)

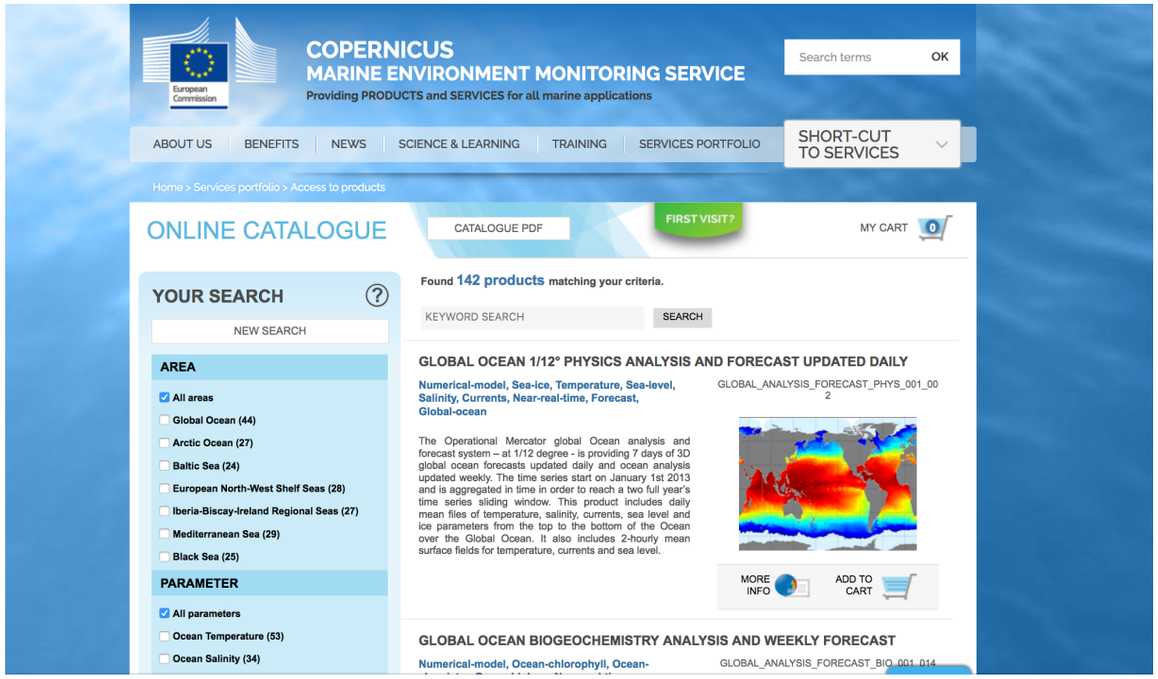
http://www.nemo-ocean.eu/

Climate **Understanding** **Operations**

- NEMO is one of the **leading ocean circulation models**
- developed (and distributed OS) by a **international consortium of 5 institutions** ,
- NEMO is the only OGCM used for all these **4 ranges of applications**
- NEMO is used in **8 ESMs** across Europe and in **Copernicus services**

Project context and background

Marine Environment Monitoring



- CMEMS products combine **observations**-based and **synthetic** model-based projects
- **Synthetic** model-based products : **physically consistant** state estimates and forecast compromising between observations and modelled physics
- Synthetic model-based products are assembled in **CMEMS Monitoring and Forecasting Centers** (MFCs)
- 6 out of 7 CMEMS Monitoring and Forecasting Centers are heavily relying on NEMO ocean model
- NEMO is also used in preparation for several **new satellite observation missions** (wide-swath altimetry, surface currents, …)

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Overall concept of IMMERSE project

- **Concept** : developing new capabilities for CMEMS by improving NEMO ocean model, used in the majority of CMEMS Monitoring and Forecasting Centers
- **Activities**: IMMERSE will accelerate the development of NEMO ocean model and prepare a seamless transition from research to operation in CMEMS, CMEMS MFCs and downstream systems.
- **In practice**, the project combines activities aiming at :
  - developing NEMO ocean model (in coordination with NEMO consortium);
  - preparing the evolution of CMEMS MFCs and downstream systems.
- **from a NEMO perspective** :
  - IMMERSE will accelerate NEMO development in order to allow a timely and seamless transition from research to operation
  - Special care as been put in adapting the project governance structure to NEMO development workflow.

To our knowledge, IMMERSE is the only H2020 project targeting explicitly the <u>development</u> of a geoscientific model.

IMMERSE project objectives

1. Develop a new, efficient, stable and scalable NEMO reference code with improved performances adapted to **exploit future HPC technologies** in the context of CMEMS systems

2. Develop NEMO for the challenges of delivering ocean state estimates and forecasts describing **ocean dynamics and biogeochemistry at kilometric scale** with improved accuracy

3. Prepare the **exploitation of the next generation of high resolution observing networks** within CMEMS systems and in detailed, downstream modelling systems.

4. Develop a flexible and generic software tools series for **interfacing CMEMS** observation and model-based products and detailed, **downstream modelling** systems

5. Provide proven model code and **software tools with assessments** suitable for rapid deployment in CMEMS

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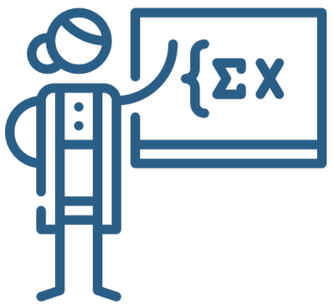
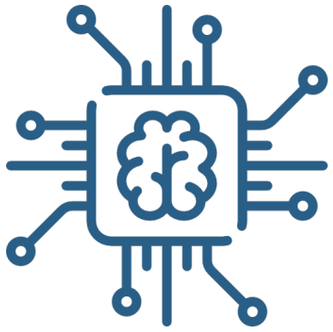
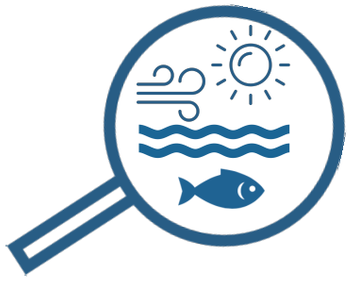
Overview of planned activities : key project WPs



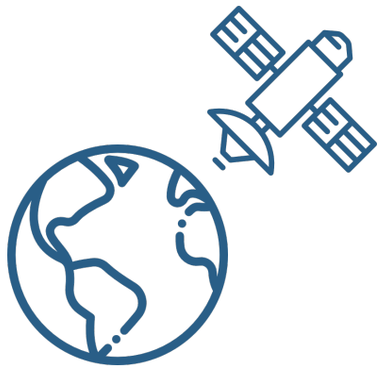
Next generation numerical kernel for NEMO



Preparing CMEMS to future HPC infrastructures



Modelling key processes at kilometric scales

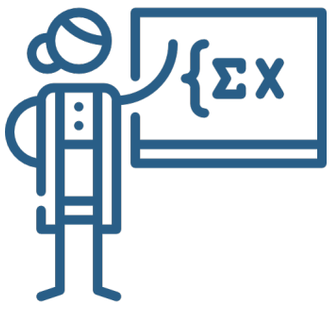


Integrating model-based products and observations

Demonstrating impact on CMEMS systems

Assessing impact on downstream systems

Overview of planned activities : work-package 3

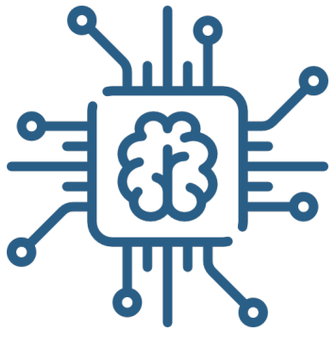


Next generation numerical kernel for NEMO

- Implement two-level time-step (2LTS) scheme
- Developments to nesting
- Develop improved algorithms for vertical coordinates
- Assess adequacy of z-tilde vertical coordinates

Towards a new kernel adapted to kilometric resolutions.

Overview of planned activities : work-package 4



Preparing CMEMS to future
HPC infrastructures

- Efficient exploitation of memory hierarchies and hardware peak performance
- Increase modularity of NEMO components - macro-task parallelism
- Efficient IOs and diagnostics for operational systems
- Load balancing for AGRIF massive multigrid capability

Continuous improvement of NEMO HPC performances.

Overview of planned activities : work-package 5

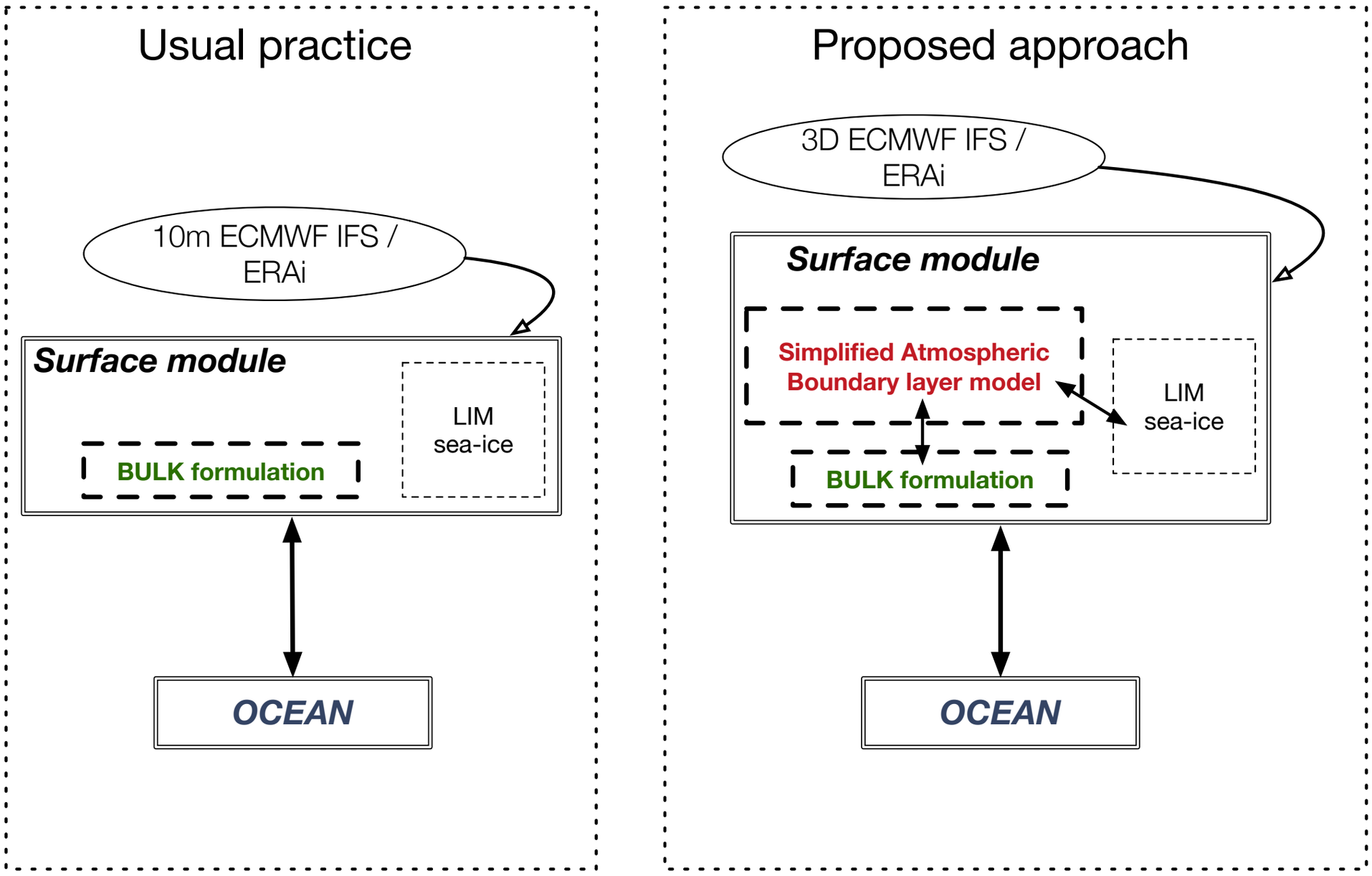
Modelling key processes
at kilometric scales

- Integration of an Atmospheric Boundary Layer model in NEMO
- Interactions between waves and O/A boundary layers processes
- Efficient and flexible interface with biogeochemical models
- Sea-Ice Rheology for high-resolution

Adapting the representation of model physics and biogeochemistry to kilometric resolutions.

Overview of planned activities : work-package 5

Modelling key processes at kilometric scales



Overview of planned activities : work-package 6

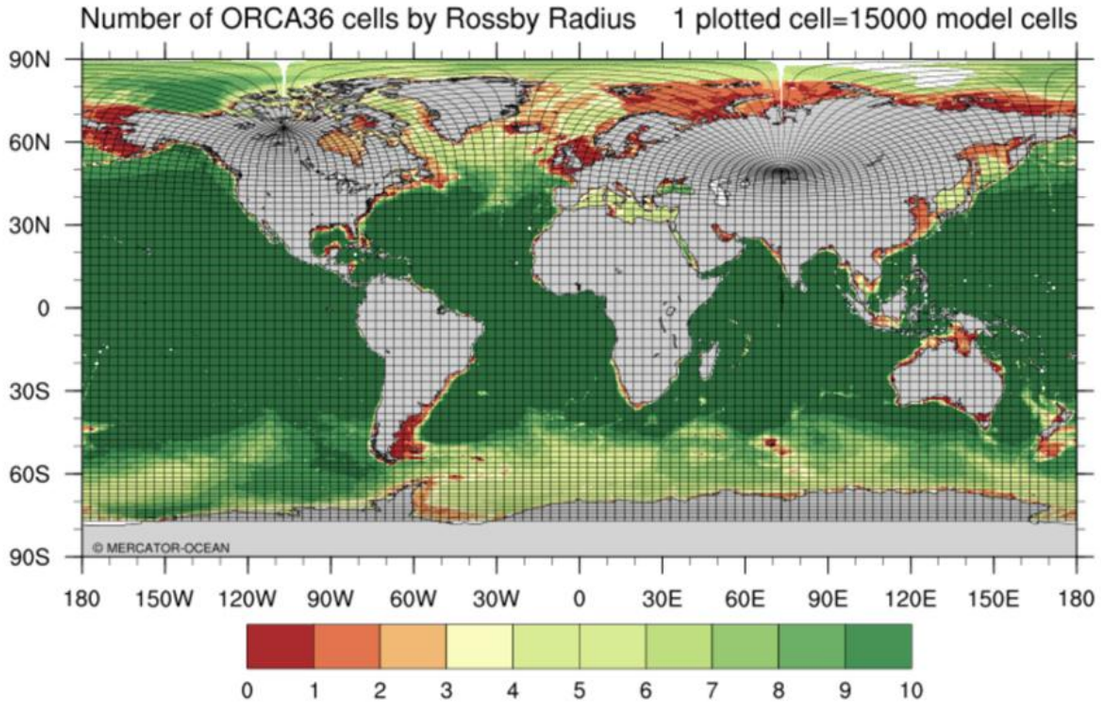
Demonstrating impact on CMEMS systems

- Impact of NEMO developments on a regional forecast framework
- Impact on reanalyses and climate modelling (overflows)
- Impact of NEMO developments on the global forecasts framework

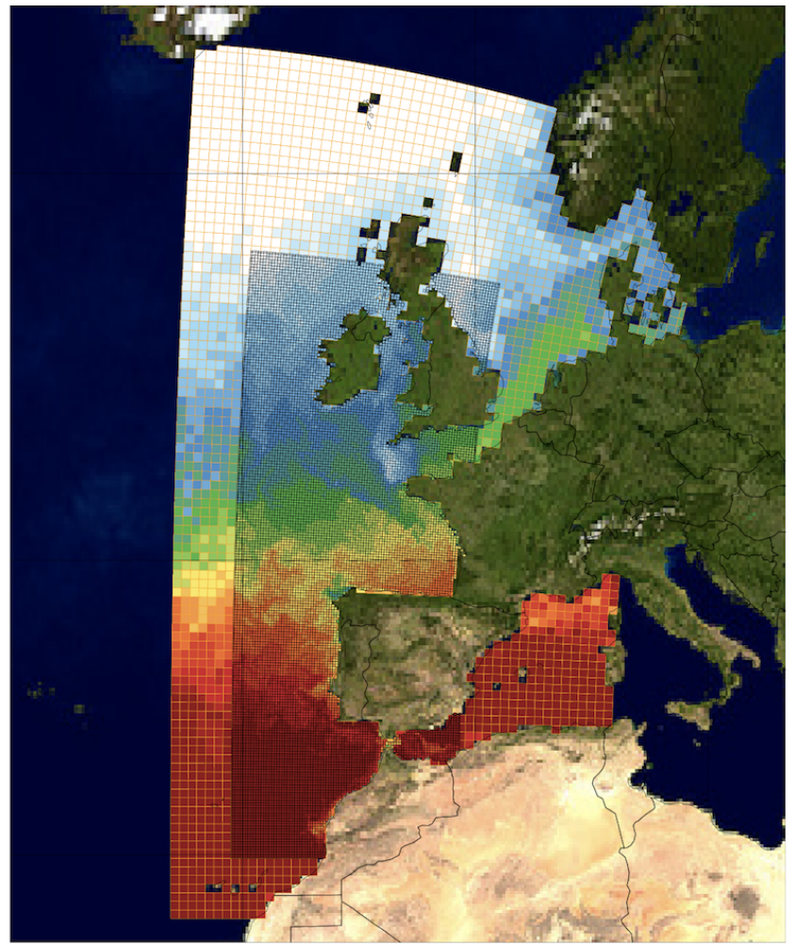
Measuring impact of NEMO developments in prototype CMEMS systems at 1/12°, 1/36° and ~1/100°
(without data-assimilation)

Overview of planned activities : work-package 6

Demonstrating impact on CMEMS systems

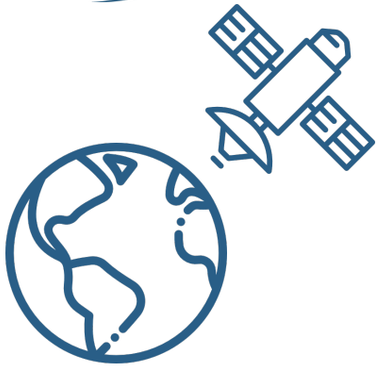


global 1/36°



IBI region + zoom ~1/100°

Overview of planned activities : work-package 7



Integrating model-based products and observations

- Ensemble quantification of short term predictability of ocean fine scale dynamics
- Statistical description of forecast accuracy in DA systems for downstream applications
- Prototype toolbox for seamless uptake of CMEMS products in downstream monitoring systems

Providing information for adapting data assimilation to kilometric resolution systems and interactions with downstream hi-res systems

Overview of planned activities : work-package 8

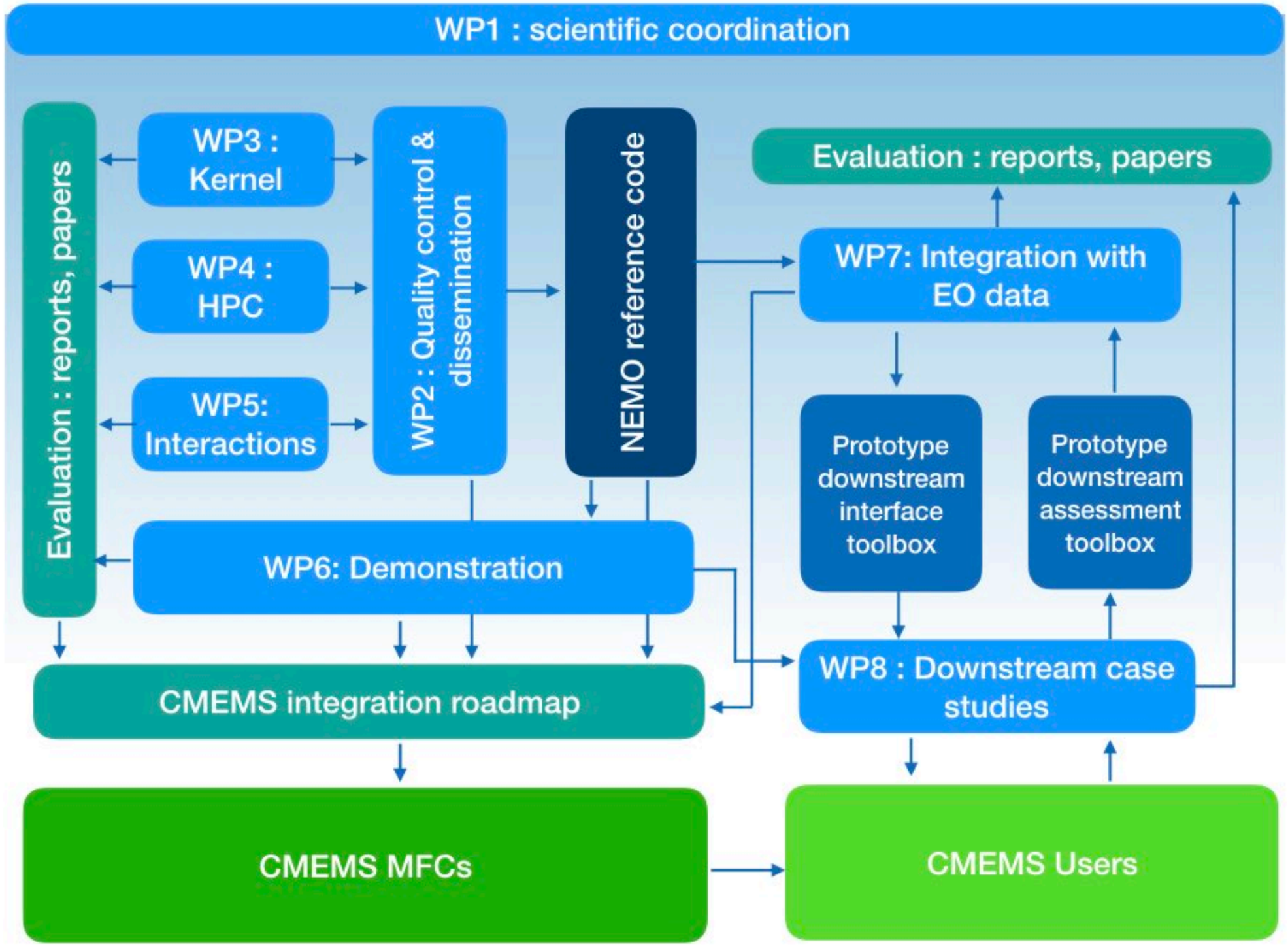
Assessing impact on
downstream systems

Testing impact in several downstream user case studies :

- Coastal processes in the German Bight
- Marine plastic litter transport from NW Europe to the Arctic
- Water quality modelling of the Tamar Estuary and adjacent coast
- Pollution transport by submesoscales in the open ocean

Assessing how changes in NEMO and CMEMS products would affect the users ability to reach their objectives.

Overview of activities : Quality control (WP2)



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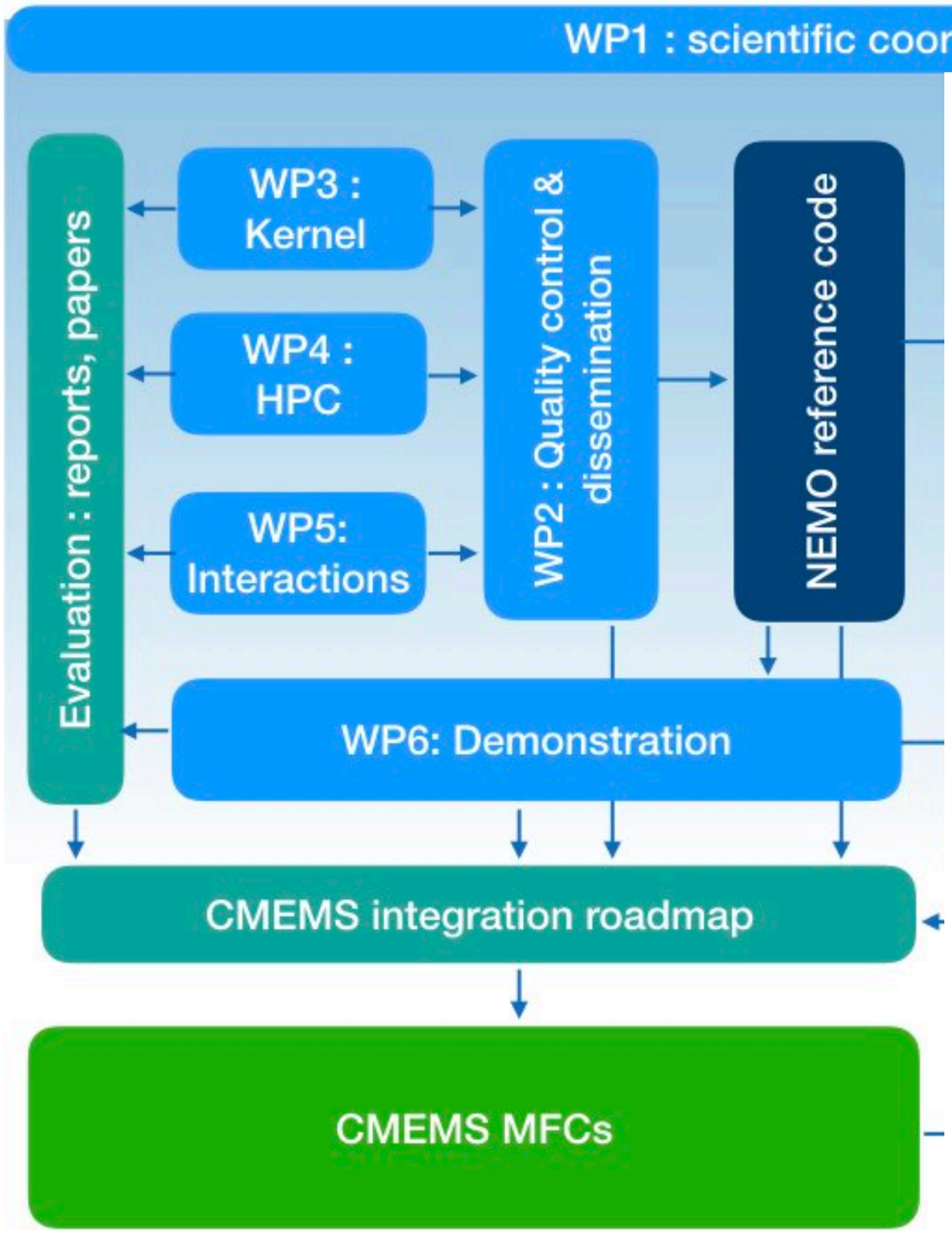

Work-package 2 :

1. Robust QC based on a series of idealised **demonstration cases** (towards test-driven development)

2. Reproducible dissemination with version control and ***digital object identifiers*** for both codes and namelists

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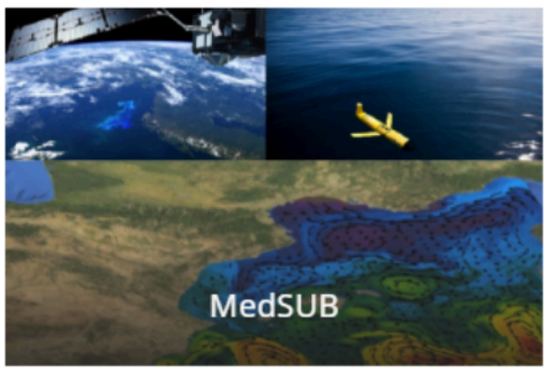
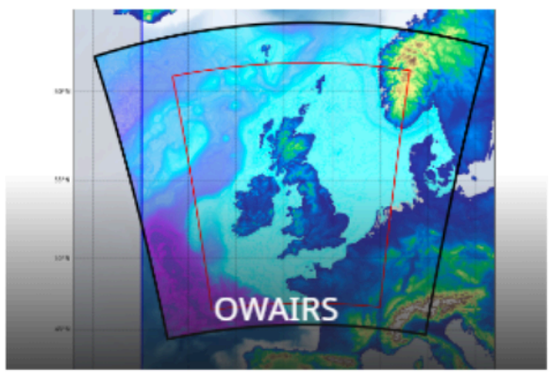
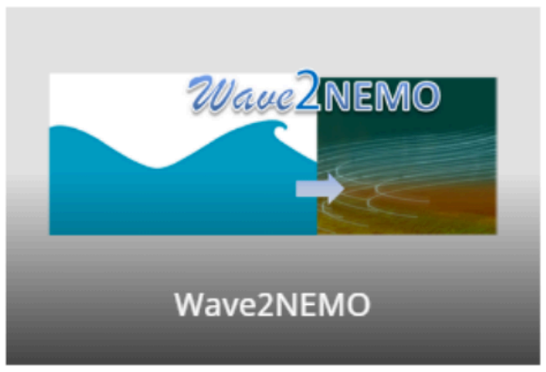
Interactions between CMEMS and IMMERSE

- A **roadmap to transition in CMEMS** and CMEMS MFCs will be delivered and updated on an annual basis.
- This roadmap will be **presented to CMEMS Scientific and Technical Advisory Committee** every year.
- IMMERSE External Expert Advisory Group (EEAB) will ensure the **liaison with key stakeholders**, including CMEMS.
- Members of IMMERSE EEAB : A. Pascual (IMEDEA), P. Brasseur (CNRS), S. Danilov (AWI), A. Sanchez Arcilla (UPC), A. Adcroft (GFDL), N. Wedi (ECMWF)
- IMMERSE shows well-defined **articulations with several CMEMS R&D Service Evolution 1 projects**, in particular with :







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- an H2020 project for improving CMEMS by improving NEMO
- preparing NEMO for kilometric resolution (HPC, Kernel, processes)
- and the integrations of the developments in CMEMS operational chains
- IMMERSE outcome will also have implications for C3S
- IMMERSE KO meeting will be held in Grenoble on 24-25 Jan 2019

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Thank you !